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TWO TECHNIQUES TO FACILITATE QUALITY ASSURANCES PROCEDURES ON MEDICAL IMAGING

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Abstract— Two methods to facilitate quality assurance indices computation are described. The first is an algorithm to automatically determine the position of the test objects centre on the image. The second allows using the image achieved for computing SNR and uniformity to also compute geometric distortion and linearity indices. These methods make possible the concurrent calculation of several quality assurance parameters without user intervention and facilitating the tests repeatability.

INTRODUCTION

In clinical environment the time available for physicists to perform quality assurance (QA) and quality control (QC) tests is limited by several factors. It is not scope of this work to discuss why and if this is right. The reality is that QA tests are often carried out in very short slots of time or out of clinical service hours. To facilitate this, many medical centres in the last years have implemented programs reducing dramatically the time needed on the scanners and leaving the majority of the computation for post-processing. In this work we describe two basic methods aimed to facilitate the computation of QA indices during post-processing. The author does not claim to be the inventor of these new methods. There are many excellent texts and publications describing quality assurance methods in different modality and using different test objects [1]. The scope of this work is to disseminate two basic techniques because these may be of large interest even though already used in some centres. We tested these methods using IQWorks™ and Matlab™ [2-4].

The first problem we addressed is that during a QA session unfortunately it is very difficult to place the test object exactly in the centre of the field of view. As a consequence the user, not knowing where the test object is located on the image, needs to select manually (during the post-processing) the position of the regions of interest (ROIs) used to compute indices such as SNR and uniformity. This operation is time consuming and reduces the repeatability of the tests. We proposed an algorithm able to automatically select on the image the centre of test objects having circular or squared section independently from where this is on the image.

The second problem we consider is that the computation of geometric distortion and linearity indices requires additional machine (scanner) time and post processing because a specific test object is used. In this work a method is introduced to evaluate geometric distortion and linearity from the image achieved using the cylindrical or spherical test object already used to compute SNR and uniformity.

METHODS

a) Preliminary screening

The aim of this subsection is to emphasize that in some particular cases before using automatic tools it is important to perform some preliminary operations.

i) Firstly for the efficiency of automatic techniques it is fundamental to eliminate from the medical image all features not related to image quality that may affect the efficiency of the automatic techniques, such as labels including clinical information and vertical and horizontal rulers. Often this is also required for security and data protection reasons. This operation can in theory be performed using text recognition algorithms but the use of Dicom editors, such as EFilmTM, is suggested.

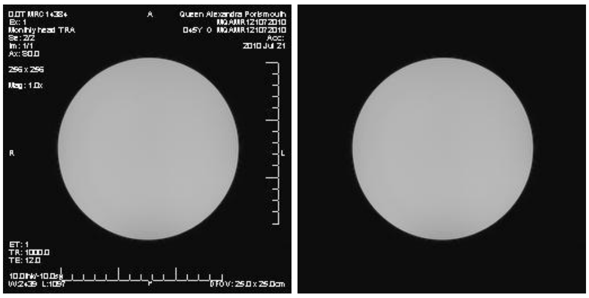

Figure 3. Elimination of labels containing medical information.

ii) Secondly it is essential to select the part of the image that is relevant to the analysis, deleting for example frames. Specific automatic algorithms for this purpose are available but again the manual cropping using Matlab™ or Dicom editors may be more efficient and it is recommended.

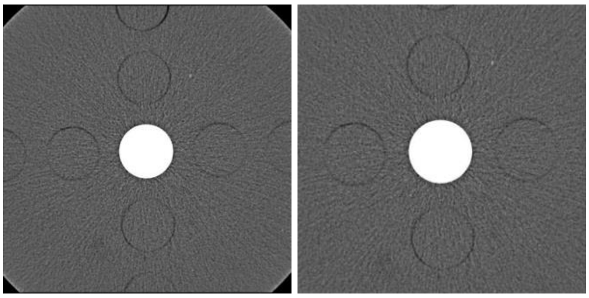

Figure 2.Elimination of framing not containing image quality information.

iii) Finally in some particular cases it is also required to optimise the image in order to achieve the best performances from the automatic technique. For example, image rotation may be required when using a phantom not having a circular section. For this purpose the use of an image editor is recommended.

Fig. 3. Elimination of unwanted rotation.

b) Automatic selection of test object centre

In order to calculate automatically the centre of the phantom, the general algorithm includes 6 main steps.

i) the first step is to compute the vertical and horizontal line profiles X(n) (blue) and Y(n) (green) of pixel values over the image. For the efficiency of the algorithm, these profiles do not need to be passing through the image centre but only to cross the test object in at least two points.

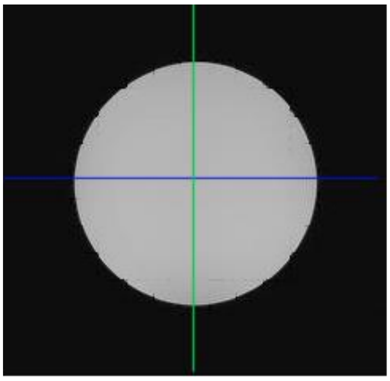

Figure 4. Selection of profiles along X and Y directions.

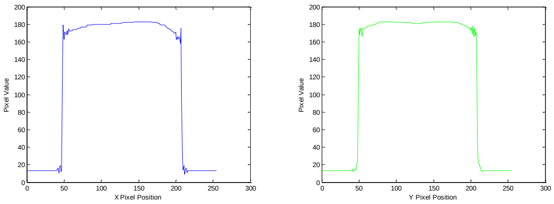

Figure 5.Pixel values profiles.

ii) The second step is to differentiate the pixel values of the line profiles. This creates two new vectors Xd(n) and Yd(n) where the value at each point is achieved from the expression

(1) $X_d(n)=X(n+1)-X(n)$ and $Y_d(n)=Y(n+1)-Y(n)$

The new vectors $X_d(n)$ and $Y_d(n)$ will have length of one element shorter than the original vectors.

iii) The third step is to compute the absolute values of the two difference vectors. This identifies the locations where there are edges.

(2) $X_{ad}(n)=abs(X_d(n))$ and $Y_{ad}(n)=abs(Y_d(n))$

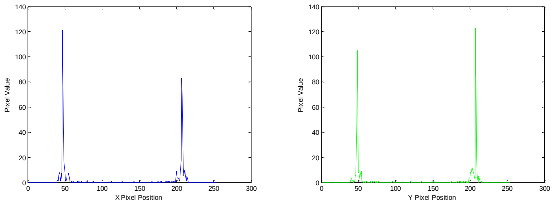

Figure 6.Edges location.

iv) The fourth step is to select the values where these absolute values are above an established threshold T. This will generate two vectors $V_x(i)$ and $V_y(j)$ of indefinite length including all the positions along the line profile where the corresponding $X_{ad}(n)$ and $Y_{ad}(n)$ are larger than T

(3) $V_x(i)$ i: $X_{ad}(i)>T$ and $V_y((j)$ j: $Y_{ad}(j)>T$

The threshold value T depends on the contrast between pixel values produced by the test object and background. This threshold selection does not need to be repeated at each test and can be used for the same medical modality. One simple way to select the threshold in advance is to note the pixel values inside and outside the test object and to use as threshold value as half of the difference.

v) The fifth step is to select the positions corresponding to first and last element of the vectors $V_x(i)$ and $V_y(j)$. This is required when test objects including internal sections are used. This operation will identify the specific edges of the test object.

(4) $V_{x1}=V_x(1)$; $V_{x2}=V_x(\text{last})$ and $V_{j1}=V_y(1)$; $V_{y2}=V_y(\text{last})$

vi) Finally the last step is to select the position corresponding to the middle points between the edges. In the presence of odd values some rounding may be required.

(5)$C_x=V_{x1}+((V_{x2}-V_{x1})/2)$ & $C_y=V_{y1}+((V_{y2}-V_{y1})/2)$

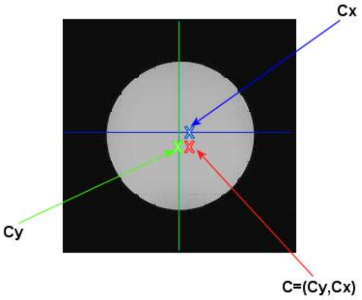

Figure 7.Selection of the centre of the test object.

The point having coordinates $C=(C_y,C_x)$ represents the centre of the test object on the image. The regions of interest needed to perform the quality assurance program can be consequentially positioned using this information in order to be sure that they are appropriately located inside or outside the area corresponding to the test object.

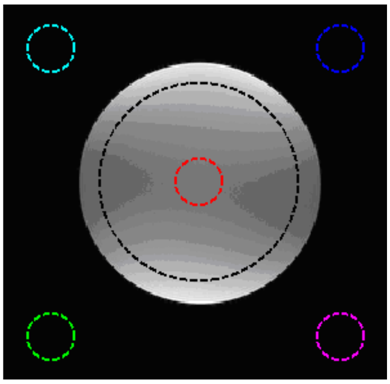

Fig 8.Region of interest location for SNR and integral uniformity.

c) Computation of the geometric linearity and distortion using a non-specific phantom

To compute the geometric distortion and linearity during a quality assurance program often specific test objects are used and the manual intervention of the user is required. Here we propose an alternative method which can be applied when the test object used is known to have circular section. The method does not require any user intervention.

The algorithm implemented essentially repeats the procedure used for selecting the centre using image profiles and selecting the positions where these profiles cross the test object. The assumption made in this case is that each line profile passes through the centre of the test object.

The general outline of the algorithm is as follows:

i) Identify the centre of the test object using the procedure seen in section b).

ii) Compute the image profiles of the pixel values passing through the centre of the test object along several directions. The accuracy of the method depends on the number of directions used. In our implementation we used 16 directions.

iii) Compute for each line profile the coordinates of the edges and therefore the distances between the edges (diameters).

(6) $D(k)$ $k=1\ldots12$

iv) Compute the geometric distortion using the expression

(7) $G_d=\text{Std}(D(k))/\text{Mean}(D(k))$

The geometric linearity can also be evaluated having information concerning pixel resolution and nominal size of the test object.

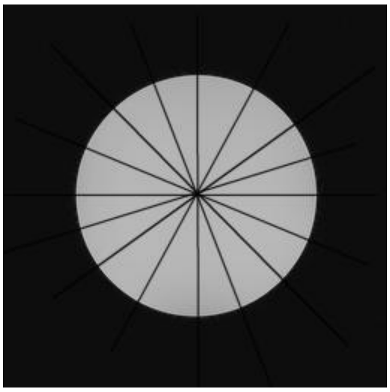

Figure 9.Line profiles for 16 directions (0º (horizontal), 11º, 23º, 34º, 45º, 56º, 68º, 79º, 90º (vertical), 101º, 113º, 124º, 135º, 146º, 158º, 169º) to compute geometric distortion and linearity.

CONCLUSIONS

We present two practical methods intended to speed up the QA indices computation. The first allows the automatic selection of the centre of the test object. This way ROIs needed for SNR and uniformity computation can be placed automatically and the parameters calculated without any user intervention. The second method results in a relevant time-saving by allowing the computation of geometric distortion and linearity indices to be made simultaneously with SNR and uniformity (and again without the manual intervention of the user).

We assessed these methods for CT and MR modalities in the Portsmouth Hospital Trust, comparing the results with those achieved using the manual ROIs selection and the ad hoc geometric distortion phantom [5]. For MR QA a comparison has also been performed between results achieved in several MR 5 medical centres situated on the south coast of England [4]. All these results show perfect consistency and repeatability. The methods are currently used during quarterly QA sessions for CT and MR.

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